APPENDIX 10

PEAK FLOW ANALYSIS

Overview

Timber harvest history, future harvest projections, and peak flow models were used to estimate percent changes in 2-year peak flow recurrence intervals within the JDSF EIR cumulative watershed effects assessment area. The degree of change in peak flow is related to the extent and type of disturbance. Peak flows were estimated for 1995 through 2009. Peak flow effects of projected harvests were estimated for all seven of the EIR alternatives. Results showed that past and projected harvests have had/would have no more than modest effects on peak flows. The greatest peak flow effects were generally seen for the earliest part of the period examined. Even for the greatest estimated changes (7.72% for the Redwood Creek planning watershed of the Upper Noyo River in 1996), the change in peak flow was not considered significant. Changes of less than 8% are within a normal range of variability, and thus not considered a significant impact. The magnitude of peak flow change estimated was found to be too small to result in changes to stream channel morphology or cause significant adverse impacts to instream habitat, water quality, or other environmental factors. The results were consistent with more detailed studies that have taken place in Caspar Creek. Namely, that disturbance to peak flow may be substantial in smaller headwater catchments, but not when evaluated at larger scales (i.e., planning watersheds, super planning watersheds, or basins).

Changes in Peak Flows Associated with Timber Operations

Introduction

Elevated peak flows can increase the frequency and magnitude of downstream overbank flooding, increase sediment transport, cause potential adverse impacts to anadromous fish habitat, add to streambank erosion, increase streamside landsliding, and produce adverse impacts to channel morphology (MacDonald and others 1991, Ziemer 1998). Research conducted in the Caspar Creek watershed on Jackson Demonstration State Forest has shown the magnitude of impact that timber harvesting can have on downstream peak flows. The results of this work were used to estimate current and future changes in peak flows associated with past and proposed future timber operations within the JDSF EIR assessment area (Figure 1).

Changes in instantaneous peak discharges in stream channels associated with timber operations have been studied for many decades, with widely varying results reported in the scientific literature (Austin 1999). Some of these differences can be explained by the use of varying definitions of peak flows (MacDonald 2000). In rain-dominated areas, timber operations can increase peak discharges by reducing interception losses, reducing evapotranspiration losses, and increasing runoff rates on compacted soil surfaces. In general, substantial canopy removal and/or new road construction in small headwater tributary basins can elevate peak discharges. MacDonald (2000) and Austin (1999) concluded, however, that past studies show that: (1) the effects of management in forested areas are unlikely to cause large changes in the hydrologic regime on a watershed scale, and (2) most studies indicate a progressively smaller change with increasing storm recurrence interval.

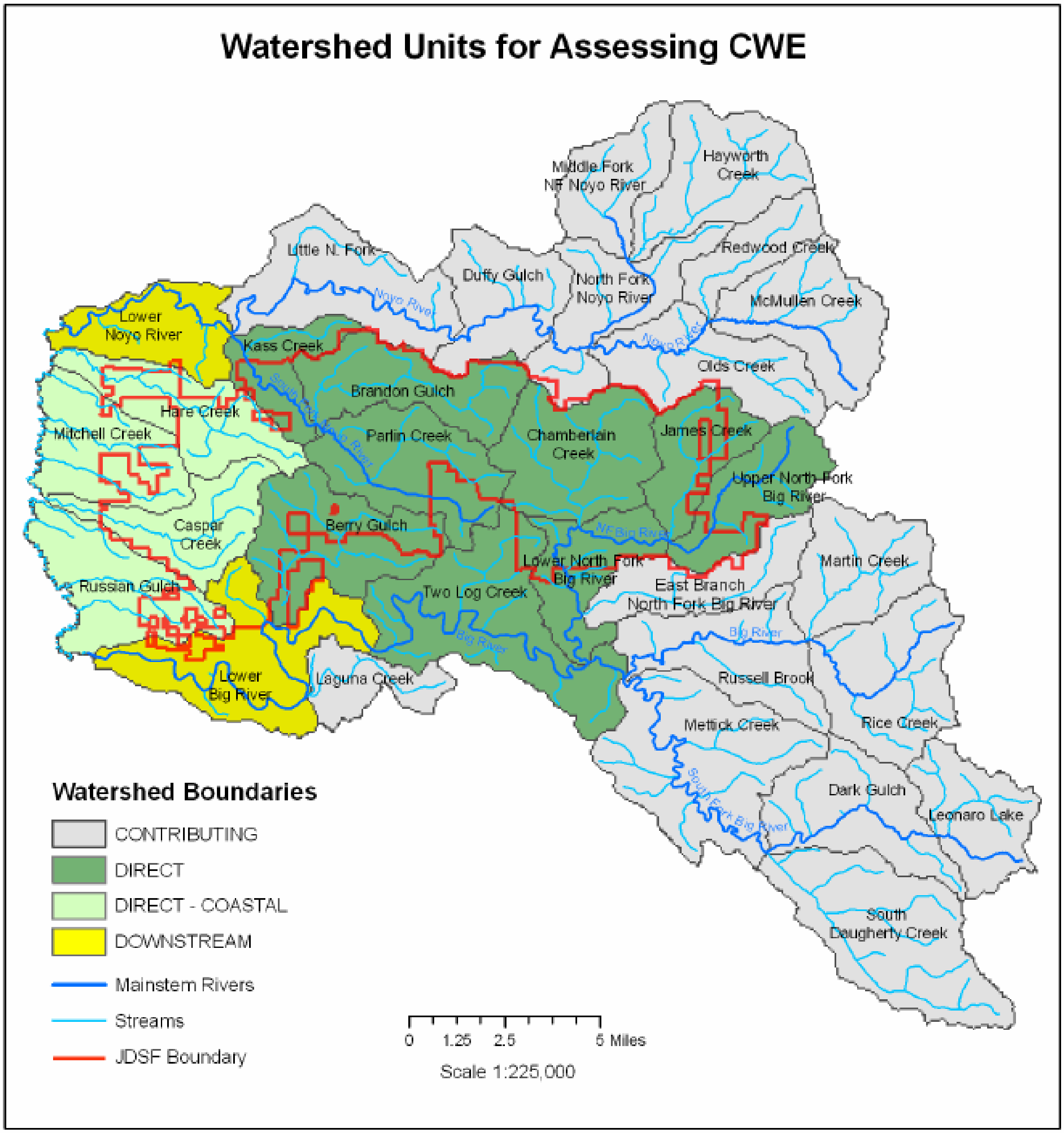

Figure 1. Cumulative watershed effects assessment area for the JDSF EIR. The JDSF boundary is outlined in red and planning watersheds are delineated in black.

In the North Fork Caspar Creek study, peakflow increases were determined to be primarily a function of vegetation removal (Lewis and others 2001) following clearcut harvesting. Peakflow increases are also known to be influenced by roads from both compacted area and changes in routing, particularly in small drainages with new road construction that directs extra water into small channels (Toman 2004). However, the majority of the road network has already been constructed within the JDSF EIR assessment area, relatively limited new construction is anticipated, some road decommissioning has occurred, and more decommissioning is planned. As a result, this peakflow analysis focused on harvest-related peak flow effects (i.e., canopy removal associated with harvesting).

Methods

Changes in past and future peak flows for the JDSF EIR assessment area were evaluated using a three-step process. First, the initial changes in instantaneous peak flows for a two-year recurrence interval runoff event on a watershed with average antecedent watershed wetness were predicted for different silvicultural systems using the Caspar Creek model developed by Lewis and others (2001). Second, these first year runoff increase values were inserted into a spatially explicit GIS model known as Delta-Q (MacDonald and Litschert 2003) to determine approximate watershed-wide changes in past two-year return period peak flows over an eleven year hydrologic recovery period for planning watersheds, super planning watersheds, and river basins in the assessment area. Finally, a similar, non-spatial analysis was used to estimate changes in 2-year return interval (RI) runoff events for the first five years (i.e., 2005-2009) of the planning period. More specific details on these approaches are provided below.

There was no attempt to estimate the changes in peak flows for more extreme events because of the rapid decline in sample size available to predict the effects of longer recurrence interval flows, which makes estimated changes in flow from extreme events progressively less reliable. However, both hydrologic theory and other field studies indicate that forest management results in progressively smaller percent changes with increasing flow magnitudes (Mount 1995, MacDonald and Litschert 2003).

Initial changes in peak flows for a given silvicultural system, wetness factor, and number of years since logging were predicted based on North Fork Caspar Creek data using the following equation (Lewis and others 2001, Lisle and others 2000):

$$E(r) = \exp\{[1+B_2(t-1)]c[B_4+B_5\ln(y_c)+B_6\ln(w)]\}$$

Where:

- r = ratio between the observed peak flow and the expected flow without a logging effect in a watershed as the result of a storm
- B_2 = logging recovery coefficient (-0.0771)
- t = number of summers since logging

- c = proportion of the watershed logged (expressed as percent canopy removed)
- B_4 = constant (1.1030)
- B_5 = storm size coefficient (-0.0963)
- y_c = expected mean peak discharge of control watersheds in Caspar Creek to a storm having the return period of the storm being estimated ($m^3s^{-1}ha^{-1}$)
- B_6 = watershed wetness coefficient (-0.2343)
- w = watershed wetness index (304 under average conditions)

The expected canopy removal associated with the different silvicultural systems used within the JDSF EIR assessment area are displayed in Table 1, along with associated first-year percent change in 2-year recurrence interval peak flows, as determined by the equation displayed above. Watershed wetness was assumed to be average at the beginning of a storm event.[1]

Next, the percent increases in initial peak flow for each silvicultural system were used in the Delta-Q model (MacDonald and Litschert 2003) to calculate the cumulative changes in flow on a watershed scale using spatial data on past harvesting stored in a GIS layer. The Delta Q program normally uses flow increases determined from flow duration curves. However, after discussion with Dr. MacDonald and comparisons of results between the Caspar Creek model and the Delta-Q model, it was determined that changes in instantaneous peak flows would have more physical meaning than flow duration curve data for estimating potential significant adverse impacts to watershed related resources.

Calculations with the Delta-Q model are based on the area affected, the number of years since the altering activity, the number of years until full hydrologic recovery, and the initial change in runoff (Figure 2). For the JDSF EIR assessment area, full hydrologic recovery was specified to occur in 11 years for all silvicultural systems (Figure 2). Peak flow recovery was calculated using the following equation:

$$D(Q) = \sum_{i=1}^{m}\left[1 - \frac{x(i)}{n}\right] * \frac{A(i)}{AWS} * d(q)$$

Where:

- $D(Q)$ = total change in flow in the watershed being modeled
- $d(q)$ = change in runoff in absolute or percentage terms for each activity type [To calculate percentages, the user must input the initial change in flow as a percent.]
- i = polygon identification number
- m = total number of affected polygons
- $x(i)$ = years since harvesting activity in area i
- n = number of years to full hydrologic recovery

[1] As defined by Lisle and others (2000), average soil wetness has a value of 304. Drier wetness factors produce larger percent changes in peak flows, while wetter factors produce smaller percent changes.

A(i) = area of activity
AWS = area of watershed

As used here, d(q) is based on the initial percent flow increase for a given change in canopy cover. The model then uses a linear decay function that decreases flow over an 11 year recovery period, as indicated by the North Fork Caspar Creek data for full hydrologic recovery (see Figure 3).

Table 1. Estimated canopy removal associated with the various silvicultural systems for past harvesting in the JDSF EIR assessment area, along with associated estimated first-year percent change in 2-year recurrence interval peak flows, as determined by the equation developed using Caspar Creek data.

Harvest Area and Period	Treatment		Canopy Removed (%)	First Year Peak Flow Increase (%)
	Symbol	Description		
Past-All	ALPR	Alternative Prescription	50	13.6
Past-All	CLCT	Clearcut	100	29.1
Past-All	CMTH	Commercial Thin	40	10.8
Past-All	CONV	Conversion	100	29.1
Past-All	GSCT	Group Selection + Commercial Thin	25	6.60
Past-All	GSLC	Group Selection Cut	20	5.24
Past-All	GSLN	Group Selection No Thin	20	5.24
Past-All	NHRV	No Harvest Area	0	0.00
Past-All	OUT	Out of THP	0	0.00
Past-All	POWR	Powerline	100	29.1
Past-All	REHAB	Rehab. of Understocked	80	22.7
Past-All	REMVCUT	Removal Cut	50	13.6
Past-All	ROAD	Road Right of Way	100	29.1
Past-All	SASV	Sanitation Salvage	20	5.24
Past-All	SHPC	Shelterwood Prep Cut	40	10.8
Past-All	SHRC	Shelterwood Removal Cut	50	13.6
Past-All	SHSC	Shelterwood Seed Cut	60	16.6
Past-All	SLCN	Selection	40	10.8
Past-All	STRC	Seed Tree Removal Cut	50	13.6
Past-All	STRT	Structure Tree Retention Treatment	85	24.3
Past-All	STSC	Seed Tree Cut	80	22.7
Past-All	TRAN	Transition	50	13.6
Past-All	VRTN	Variable Retention	80	22.7

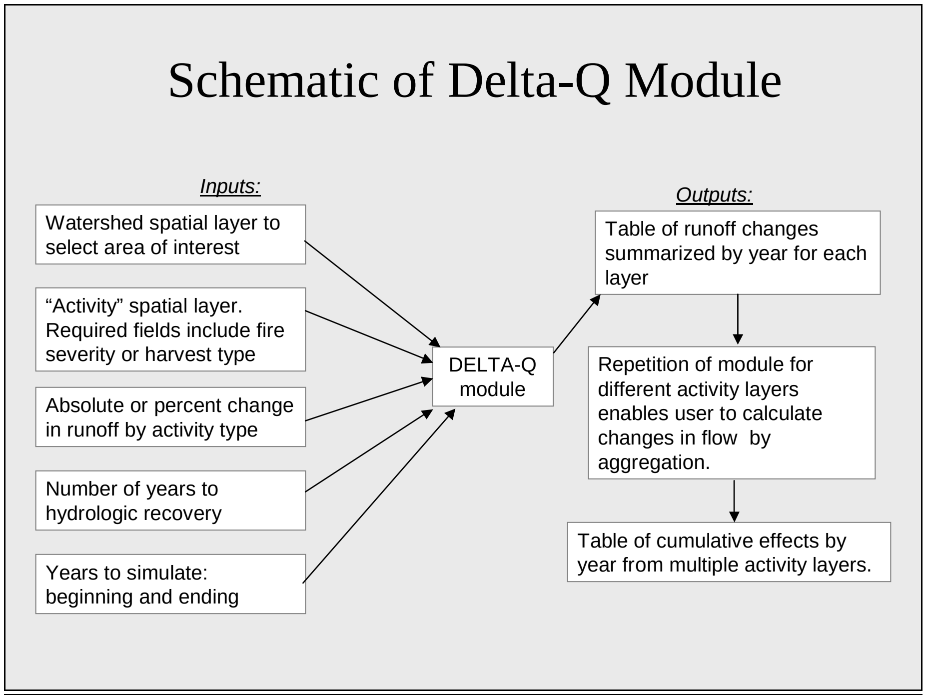

Figure 2. Schematic diagram of the Delta-Q model developed by Dr. Lee MacDonald and Ph.D candidate Sam Litschert. Graphic prepared by Dr. MacDonald, CSU, Fort Collins, CO.

The model was run at three spatial scales: planning watershed (typically 5,000 to 10,000 acres), sub-basin (i.e. super planning watershed, typically 20,000 to 50,000 acres), and river basin (typically 50,000 to 100,000+ acres). A time period covering 1995 to 2004 was used for analysis of past harvesting impacts.

Results and Discussion

Results of the peak flow analysis for past harvesting the Big and Noyo River basins and four small coastal drainages are displayed in Tables 2 and 3 at the planning watershed, super planning watershed, and river basin scale for each drainage in the JDSF EIR assessment area. A map of the JDSF EIR assessment area is presented as Figure 1. As discussed in more detail below, changes of less than 8% are clearly within the normal range of variability of stream flow for the Coast Range and are not anticipated to adversely affect water quality.

As displayed in Figure 4, the increase in 2-year recurrence interval instantaneous peak flows associated with past canopy removal for the eight super planning watersheds has clearly been decreasing or remaining relatively constant over the past decade. A bar chart displaying a typical recovery pattern is displayed for the South Fork Noyo River super planning watershed in Figure 5. This recovery pattern indicates that increases in peak flows have returned to near “normal” levels as tree canopy has regrown since the periods of more intensive harvest in the 1980s.

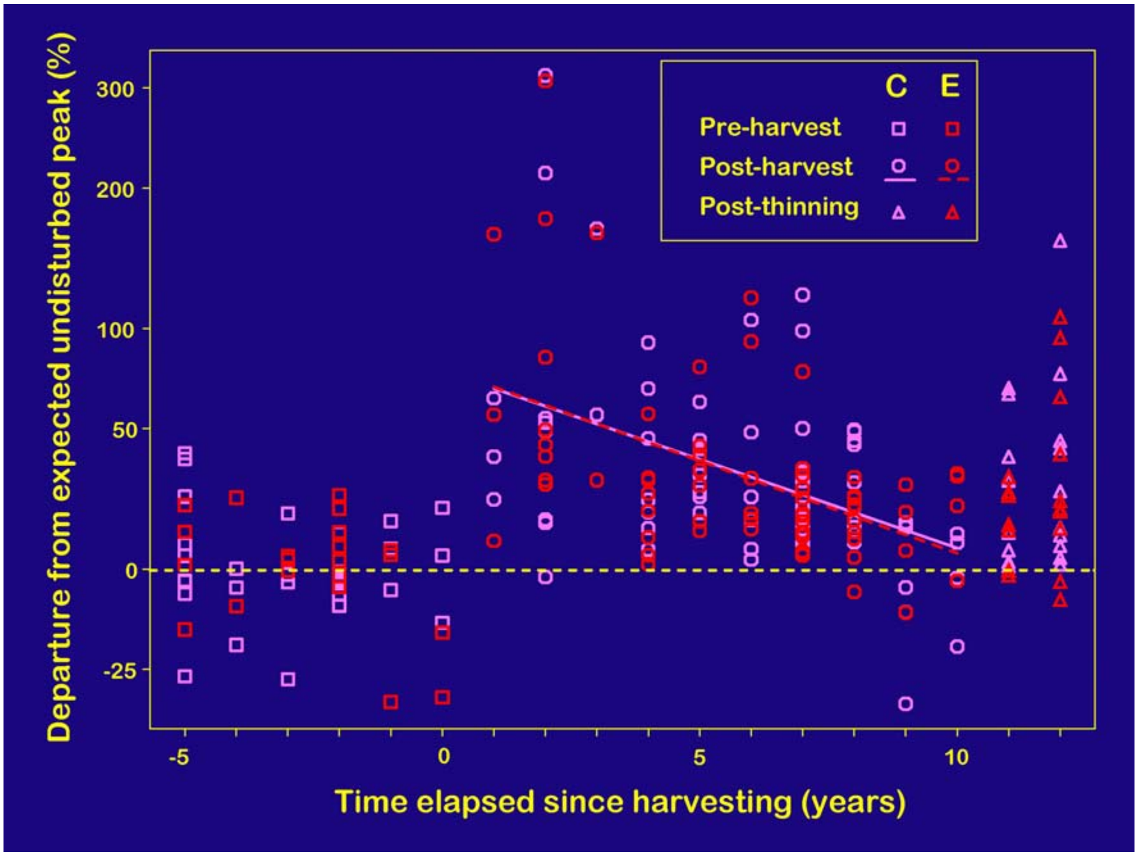

Figure 3. Graphical display of departures from expected peak flows based on pretreatment calibration for sub-watersheds CAR and EAG in the North Fork of Caspar Creek. The average peak flow increase was 26% for CAR and EAG combined, both of which were clearcut harvested. Full recovery would have occurred in approximately 11 years had pre-commercial thinning not occurred in year 11. Graphic produced by Mr. Jack Lewis, USFS-PSW, Arcata, CA.

Table 2. Estimated increases in 2-year recurrence interval instantaneous peak discharges associated with timber harvesting (not including road impacts) for the Big River watershed planning watersheds, super planning watersheds, and river basin within the JDSF EIR assessment area.

PLANNING WATERSHED		Peak Flow Change									
Sub-Watershed	Drainage Area (mi^2)	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004
UPPER BIG RIVER	**32.81**	4.87	4.72	4.44	3.86	3.25	2.87	2.38	1.83	1.34	0.96
Martin Creek	9.29	5.55	5.81	5.68	4.87	4.09	3.32	2.67	2.03	1.49	0.94
Russell Brook	10.96	3.88	3.33	2.7	2.38	1.93	1.99	1.79	1.45	1.13	1.01
Rice Creek	12.56	5.24	5.12	5.05	4.41	3.77	3.32	2.67	2.01	1.41	0.92
NORTH FORK BIG RIVER	**43.49**	3.07	2.66	2.51	2.11	1.72	1.38	1.16	0.89	0.67	0.48
Upper North Fork Big River	8.46	4.55	4.26	4.38	3.69	3.02	2.39	1.81	1.34	0.86	0.5
James Creek	6.96	1.63	1.44	1.43	1.23	1.03	0.94	0.77	0.63	0.49	0.35
Chamberlain Creek	12.28	0.05	0.05	0.06	0.05	0.05	0.05	0.04	0.03	0.03	0.02
East Branch North Fork Big	8.06	4.39	3.47	2.93	2.23	1.54	0.99	0.63	0.41	0.34	0.28
Lower North Fork Big River	7.73	1.38	1.17	1	1.06	1.1	1.06	1.33	1.13	0.96	0.8
SOUTH FORK BIG RIVER	**54.51**	1.96	2.01	1.7	1.87	1.77	1.88	1.87	1.83	1.66	1.79
Dark Gulch	11.18	1.04	2.28	2.01	2.17	2.03	1.96	1.8	1.51	1.38	1.08
South Daugherty Creek	16.67	3.62	3.1	2.56	3.01	2.84	3.41	3.03	2.68	2.21	3
Mettick Creek	18.33	1.39	1.32	1.13	1.17	1.16	1.07	1.51	1.95	1.98	1.87
Leonaro Lake	8.33	1.09	0.97	0.84	0.72	0.6	0.5	0.41	0.31	0.22	0.12
LOWER BIG RIVER	**50.35**	3.83	3.62	3.62	3.18	2.95	2.7	2.6	2.26	1.9	1.67
Laguna Creek	5.07	6.46	5.59	6.55	5.9	5.44	5.34	4.36	3.42	2.48	2.83
Berry Gulch	12.50	2.87	2.72	2.21	1.74	1.52	1.14	1.36	1.24	1	0.79
Mouth of Big River	14.92	4.21	4.36	3.7	3.36	3.4	3.18	2.65	2.15	1.66	1.32
Two Log Creek	17.86	3.47	3.09	3.71	3.28	2.89	2.65	2.93	2.74	2.58	2.26
BIG RIVER WATERSHED	**181.16**	3.29	3.14	2.95	2.69	2.4	2.23	2.05	1.78	1.49	1.35

Table 3. Estimated increases in 2-year recurrence interval instantaneous peak discharges associated with timber harvesting (not including road impacts) for the Noyo River watershed planning watersheds, super planning watersheds, and river basin within the JDSF EIR assessment area.

PLANNING WATERSHED		Peak Flow Change									
Sub-Watershed	Drainage Area (mi^2)	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004
UPPER NOYO RIVER		***3.37***	***3.49***	***3.43***	***3.17***	***2.95***	***2.82***	***2.61***	***2.61***	***2.39***	***2.16***
Redwood Creek	5.26	5.32	7.72	6.87	6.02	6.05	5.12	4.86	4	3.54	3.34
Olds Creek	10.89	2.96	3.25	3.91	3.48	2.95	2.4	2.2	1.81	2.09	2.17
Hayworth Creek	11.11	3.16	3.14	2.87	2.9	2.7	3.07	2.74	2.59	2.14	1.69
Middle Fork N. Fork Noyo River	7.14	3.94	3.18	3.56	2.81	2.04	2.59	2.25	2.74	2.97	2.52
North Fork Noyo River	10.19	3.77	3.62	3.27	3.54	3.03	3.06	3.23	2.65	2.14	1.67
McMullen Creek	11.05	2.33	2.16	1.97	1.66	2.22	1.83	1.49	2.62	2.25	2.31
MIDDLE NOYO RIVER		***4.59***	***3.7***	***3.13***	***2.33***	***2.15***	***1.81***	***1.46***	***1.37***	***1.16***	***1.02***
Little North Fork	13.18	4.83	3.96	3.19	2.17	1.74	1.28	1.01	0.8	0.67	0.64
Duffy Gulch	8.96	4.23	3.32	3.05	2.57	2.76	2.59	2.13	2.22	1.88	1.59
SOUTH FORK NOYO RIVER		***3.45***	***3.79***	***3.74***	***3.66***	***4.07***	***3.47***	***2.96***	***2.53***	***2.12***	***1.67***
Brandon Gulch	10.08	0.76	1.3	2.05	2.36	3.55	3.13	2.7	2.53	2.14	1.76
Parlin Creek	11.84	5.36	5.07	4.88	4.48	4.62	3.86	3.16	2.55	2.02	1.53
Kass Creek	5.52	4.27	5.59	4.4	4.28	3.85	3.24	2.98	2.46	2.27	1.8
LOWER NOYO RIVER		***2.44***	***1.97***	***1.99***	***1.54***	***1.43***	***1.4***	***1.18***	***1***	***0.79***	***0.63***
Mouth of Noyo River	8.16	2.44	1.97	1.99	1.54	1.43	1.4	1.18	1	0.79	0.63
NOYO RIVER WATERSHED	113.38	***3.56***	***3.5***	***3.35***	***3.01***	***2.95***	***2.68***	***2.37***	***2.23***	***1.97***	***1.71***
COASTAL WATERSHEDS											
Hare Creek	9.66	2.59	3.38	3.48	2.81	3.5	3.06	2.69	2.18	1.93	1.54
Caspar Creek	8.38	2.68	2.17	1.64	1.38	1.05	0.79	0.64	0.45	0.37	0.25
Russian Gulch	11.09	0.16	0.26	0.23	0.23	0.2	0.17	0.36	0.31	0.26	0.24
Mitchell Creek	10.24	0.21	0.18	0.16	0.14	0.28	0.28	0.24	0.21	0.18	0.14

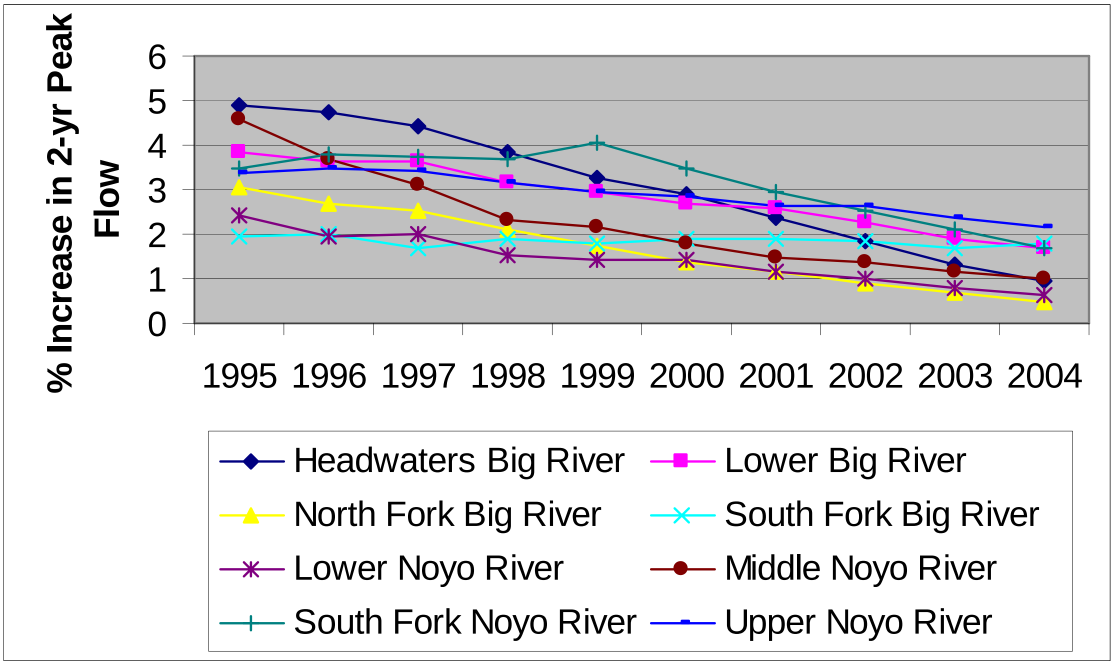

Figure 4. Estimated percent increase in 2-year recurrence interval instantaneous peak discharge for the 8 super planning watersheds over the past 10-year period.

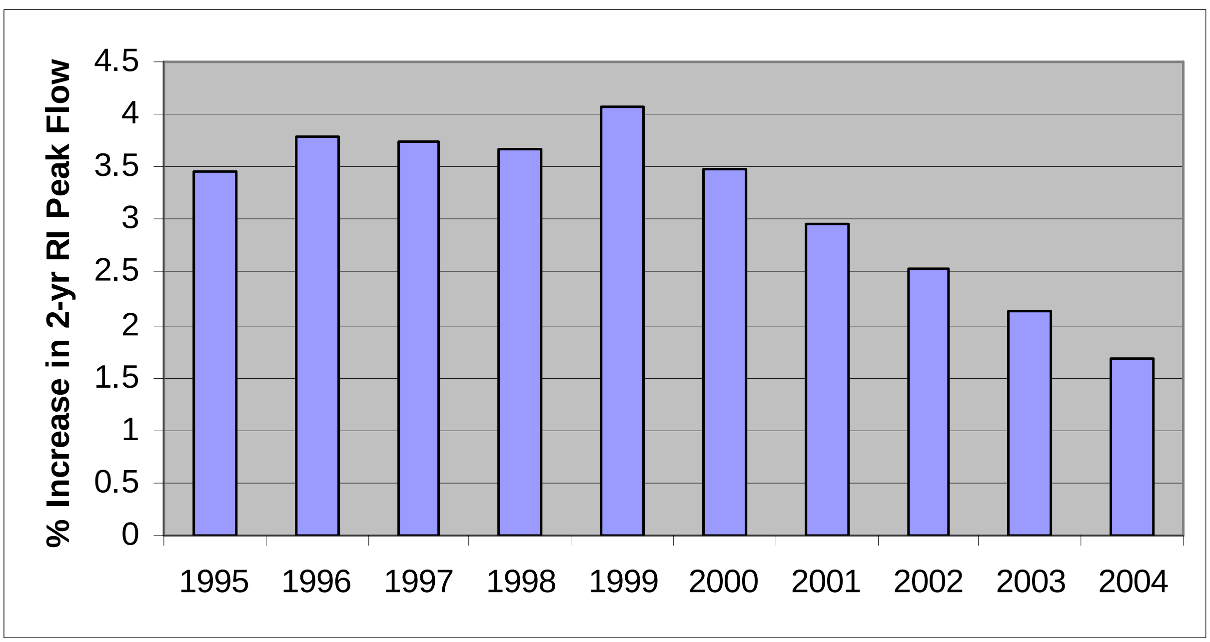

Figure 5. Example of estimated percent increase in 2-year recurrence interval instantaneous peak discharge from 1995 through 2004 using the South Fork Noyo River super planning watershed.

Effect of Scale on Harvesting Related Peak Flow Increases

The effect of past harvesting (i.e., canopy removal) on 2-year RI instantaneous peak flows was found to change with watershed scale. As shown in Figure 6, there are three categories of modeled maximum percent increase in instantaneous peak discharge (2-year return interval) under average moisture conditions from 1995 to 2004 for the planning watersheds within the JDSF EIR assessment area. The largest increases were found at the planning watershed scale. Maximum predicted changes in peak flow were 7.72% in the Redwood Creek planning watershed and 6.55% for Laguna. The variation in predicted changes in peak flow was also most pronounced at the planning watershed level, with maximum predicted change ranging from 7.72% in Redwood Creek to only 0.06% in the Chamberlain Creek planning watershed (Table 4 and Figure 7). At the super planning watershed scale, the maximum increases were 4.87% for Upper Big River, 4.59% for the Middle Noyo River, and 4.07% for the South Fork Noyo River (Tables 2 and 3). The maximum increase at the river basin scale for the period from 1995 to 2004 was 3.56% in the Noyo River watershed and 3.29% in the Big River basin (both occurring in 1995).

Earlier work in Caspar Creek shows that the trend in larger maximum percent change in peak flows with smaller watersheds continues as the drainage size decreases. For example, 190-acre to 1,170-acre watersheds that were partially harvested (30-50% clearcut) had 2-year RI peak flows increase on average 14.6%, while smaller headwater tributary basins (approximately 25 to 65 acres), had an average 2-year RI increase of 27% for entirely clearcut watersheds (Ziemer 1998). At a much smaller watershed scale, Ziemer (1992, 1998) found that a 2.5-acre headwater swale (zero order) had up to a 370% increase in peak pipeflow discharges over uncut conditions, but the recurrence interval for this percent increase was not reported.[2]

[2] Ziemer (1998) states that all but two of the pipeflow discharge measurements after logging were from moderate storms.

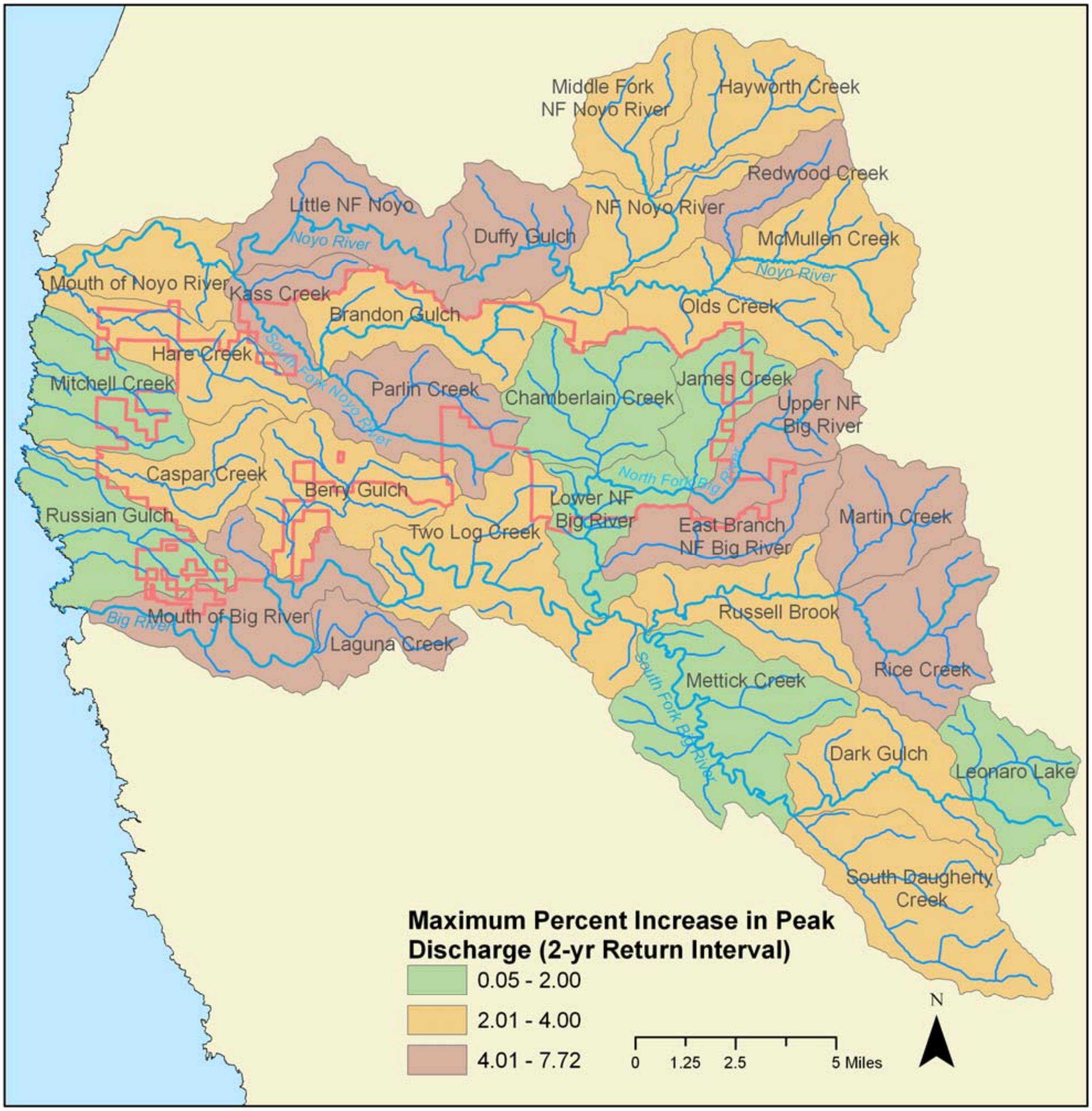

Figure 6. Modeled maximum percent increase in instantaneous peak discharge (2-year return interval) under average moisture conditions from 1995 to 2004 for planning watersheds within the JDSF EIR assessment area.

Table 4. Maximum estimated increases in 2-year recurrence interval instantaneous peak discharges associated with timber harvesting (not including road impacts) for the planning watersheds within the JDSF EIR assessment area for the period from 1995 to 2004.

Planning Watershed Name	Year of Maximum Change	Maximum Percent Change
Berry Gulch	1995	2.87
Brandon Gulch	1999	3.55
Caspar Creek	1995	2.68
Chamberlain Creek	1997	0.06
Dark Gulch	1996	2.28
Duffy Gulch	1995	4.23
East Branch North Fork Big River	1995	4.39
Hare Creek	1997	3.48
Hayworth Creek	1995	3.16
James Creek	1995	1.63
Kass Creek	1996	5.59
Laguna Creek	1997	6.55
Leonaro Lake	1995	1.09
Little N. Fork	1995	4.83
Lower North Fork Big River	1995	1.38
Martin Creek	1996	5.81
McMullen Creek	2002	2.62
Mettick Creek	2003	1.98
Middle Fork N. Fork Noyo River	1995	3.94
Mitchell Creek	1999, 2000	0.28
Mouth of Big River	1996	4.36
Mouth of Noyo River	1995	2.44
North Fork Noyo River	1995	3.77
Olds Creek	1997	3.91
Parlin Creek	1995	5.36
Redwood Creek	1996	7.72
Rice Creek	1995	5.24
Russell Brook	1995	3.88
Russian Gulch	2001	0.36
South Daugherty Creek	1995	3.62
Two Log Creek	1997	3.71
Upper North Fork Big River	1995	4.55

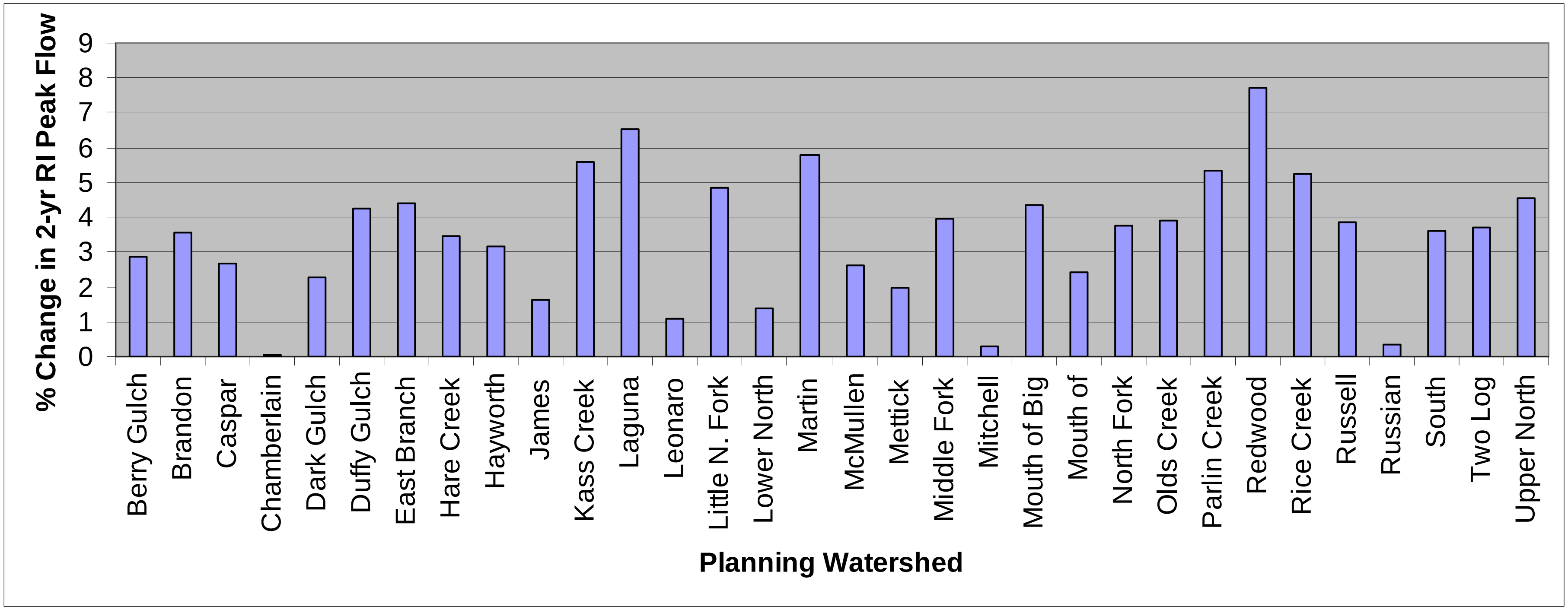

Figure 7. Maximum estimated increase in 2-year recurrence interval instantaneous peak discharges associated with timber harvesting (not including road impacts) for the planning watersheds within the JDSF EIR assessment area for the period 1995 to 2004.

As has been found elsewhere, this comparison shows that the effects of forest practices on storm runoff are more pronounced in small watersheds than in large basins. Ziemer and Lisle (1998) and Ziemer (1992) report that smaller catchments are more responsive to forest cutting than larger basins because the stormflow response of small basins is governed primarily by hillslope processes, which are sensitive to forest practices such as the presence of roads. Additionally, the effects of timber operations on small watersheds is larger because a large percentage of a small basin may be affected at one time (Ziemer 1998, USFWS and CDF 1999). In contrast, stormflow response of larger basins is governed primarily by geomorphology of the channel network, which is less likely to be affected by forest practices. Downstream changes tend to be attenuated by channel storage and mixing with runoff from unaffected areas. Ziemer and Rice (1990) reported that the gaged portion of the North Fork of Caspar Creek behaves like a "small" watershed, responding mainly to watershed conditions and failing to show channel storage effects. Therefore, the 1,170-acre North Fork of Caspar Creek and its tributaries can be considered “small” watersheds, while the 5,360 acre Caspar Creek planning watershed can be classified a “large” watershed. More broadly, the scale of watersheds delivering flows from JDSF can be considered “large” watersheds, and the modeling results show that they are not highly sensitive to harvesting impacts related to changes in 2-year return interval instantaneous peak flow events.

Comparison of Projected Changes in Peak Flows with the Different EIR Alternatives

Following the analysis of past peak flow effects, changes in future peak flows in the assessment area were estimated for the initial five-year period of the proposed project. The future peak flow analysis was limited to five years because projections of harvest activity beyond this point was deemed too speculative. This analysis of future peak flow effects was conducted using the same assumptions and equations as were applied to the calculation of peak flow effects from past harvesting, except that projected harvesting levels were estimated at the planning watershed level (non-spatially) rather than from existing harvest units in the GIS database. This nonspatial approach was used due to uncertainty as to specific locations of anticipated harvesting.

Projected peak discharges were calculated for each of the seven EIR alternatives over the first five-year planning period (2005-2009) based on expected harvesting both on and off JDSF within the EIR assessment area. On Mendocino Redwood Company (MRC) timberlands within the assessment area, silvicultural prescriptions and estimated acres in the various planning watersheds were provided by MRC. For the other timberlands in the assessment area outside of JDSF, harvesting over the first five years was assumed to be similar to what had occurred over the past five years and were modeled from projected Wildlife Habitat Relationship (WHR) categories.[3] Expected silvicultural systems for future harvesting and related canopy removal and peak flow factors are shown in Table 5, and projected future peak flow increases are summarized

[3] California Wildlife Habitat Relationships (CWHR) is a community-level matrix model for predicting wildlife habitat relationships for 675 regularly-occurring terrestrial vertebrates in California.

in Tables 6 and 7. Table 6 shows the results for each alternative, and Table 7 shows how much each active management alternative (alternatives B through F) differs from the no management alternative (alternative A).

Table 5. Estimated canopy removal associated with the various silvicultural systems for proposed harvesting in the JDSF EIR assessment area, along with associated estimated first-year percent change in 2-year recurrence interval peak flows, as determined by the equation developed using Caspar Creek data.

Period and Harvest Area	Treatment		Canopy Removed (%)	First Year Peak Flow Increase (%)
	Symbol	Description		
Future-JDSF	AALT	Late Seral Development	25	6.60
Future-JDSF	CMTH	Commercial Thin	40	10.8
Future-JDSF	GSLN	Group Selection No Thin	20	5.24
Future-JDSF	SLCN	Selection	40	10.8
Future-JDSF	STRT	Structure Tree	85	24.3
Future Non-JDSF	CLCT	Clearcut	100	29.1
Future Non-JDSF	CMTH	Commercial Thin	40	10.8
Future Non-JDSF	GSLN	Group Selection No Thin	20	5.24
Future Non-JDSF	REHAB	Rehab. of Understocked	80	22.7
Future Non-JDSF	RH1	Rehabilitation	70	19.6
Future Non-JDSF	SASV	Sanitation Salvage	20	5.24
Future Non-JDSF	SEL	Selection	20	5.24
Future Non-JDSF	SEL_HR	High Retention Selection	15	3.91
Future Non-JDSF	SEL_YNG	Young Stand Selection	25	6.60
Future Non-JDSF	SEL2	High Stocked Retention	20	5.24
Future Non-JDSF	SHPC	Shelterwood Prep Cut	40	10.8
Future Non-JDSF	SHRC	Shelterwood Removal Cut	50	13.6
Future Non-JDSF	SHSC	Shelterwood Seed Cut	60	16.6
Future Non-JDSF	SLCN	Selection	40	10.8
Future Non-JDSF	STR	Seed Tree Removal	25	6.60
Future Non-JDSF	STRC	Structure Tree Retention Treatment	85	24.3
Future Non-JDSF	STSC	Seed Tree Cut	80	22.7
Future Non-JDSF	TRAN	Transition	50	13.6
Future Non-JDSF	VR1	Variable Retention I	65	18.1
Future Non-JDSF	VR2	Variable Retention II	70	19.6
Future Non-JDSF	VR3	Variable Retention III	80	22.7

Table 6. Results of the peak flow analysis for individual planning watersheds and the various JDSF management alternatives for the reasonably foreseeable period of 2005 to 2009. Values displayed are for year 2009, the final year modeled in the analysis.

Planning Watershed	Peak Flow Change (%) by Management Alternative (A-F)						
	A	B	C1	C2	D	E	F
Redwood Cr.	1.106	1.106	1.106	1.106	1.106	1.106	1.106
Olds Cr.	2.192	2.192	2.192	2.192	2.192	2.192	2.192
Hayworth Cr.	1.585	1.585	1.585	1.585	1.585	1.585	1.585
Noyo River MFNF	2.678	2.678	2.678	2.678	2.678	2.678	2.678
Noyo River NF	1.868	1.868	1.868	1.868	1.868	1.868	1.868
McMullen Cr.	1.681	1.681	1.681	1.681	1.681	1.681	1.681
Noyo River LNF	2.626	2.630	2.630	2.630	2.636	2.632	2.626
Duffy Gulch	2.671	2.671	2.671	2.671	2.671	2.671	2.671
Brandon Gulch	0.291	2.430	2.540	2.540	2.346	1.147	0.293
Parlin Cr.	0.626	2.317	2.262	2.262	2.248	1.250	1.913
Kass Cr.	1.597	1.710	1.709	1.709	1.732	1.664	1.668
Hare Cr.	0.568	1.404	1.373	1.373	1.270	0.884	1.368
Mitchell Cr.	0.324	0.824	0.793	0.793	0.750	0.526	0.684
Noyo River Mouth	0.976	0.976	0.976	0.976	0.976	0.976	0.976
Dark Gulch	1.128	1.128	1.128	1.128	1.128	1.128	1.128
S. Daugherty Cr.	3.141	3.141	3.141	3.141	3.141	3.141	3.141
Mettick Cr.	3.612	3.612	3.612	3.612	3.612	3.612	3.612
Leonaro Lake	0.463	0.463	0.463	0.463	0.463	0.463	0.463
Martin Cr.	0.074	0.074	0.074	0.074	0.074	0.074	0.074
Russell Brook	1.382	1.382	1.382	1.382	1.382	1.382	1.382
Rice Cr.	0.206	0.206	0.206	0.206	0.206	0.206	0.206
James Cr.	0.145	0.145	0.145	0.145	0.145	0.145	0.145
Chamberlain Cr.	0.000	1.470	1.337	1.337	1.046	0.454	0.615
Big River EBNF	0.253	0.253	0.253	0.253	0.253	0.253	0.253
Big River LNF	0.951	1.141	1.126	1.126	1.125	1.040	1.093
Big River UNF	0.086	0.086	0.086	0.086	0.086	0.086	0.086
Laguna Cr.	2.073	2.073	2.073	2.073	2.073	2.073	2.073
Berry Gulch	0.916	2.130	1.946	1.943	1.858	1.341	1.667
Big River Mouth	0.762	0.882	0.871	0.865	0.885	0.818	0.762
Caspar Cr.	0.055	0.615	0.563	0.563	0.719	0.369	0.477
Russian Gulch	0.383	0.383	0.383	0.383	0.383	0.383	0.383
Two Log Cr.	2.547	2.794	2.776	2.774	2.793	2.655	2.747

Table 7. Results of the peak flow analysis for individual planning watersheds compared to the no harvesting alternative for the various JDSF management alternatives. Values displayed are for year 2009, the final year modeled in the analysis.

Planning Watershed	Peak Flow Differences (%) from No Harvesting Alternative						
	A	B	C1	C2	D	E	F
Redwood Cr.	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Olds Cr.	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Hayworth Cr.	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Noyo River MFNF	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Noyo River NF	0.000	0.000	0.000	0.000	0.000	0.000	0.000
McMullen Cr.	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Noyo River LNF	0.000	0.005	0.005	0.005	0.010	0.006	0.000
Duffy Gulch	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Brandon Gulch	0.000	2.139	2.249	2.249	2.054	0.856	0.001
Parlin Cr.	0.000	1.691	1.636	1.636	1.621	0.624	1.287
Kass Cr.	0.000	0.113	0.112	0.112	0.135	0.067	0.071
Hare Cr.	0.000	0.836	0.804	0.804	0.701	0.316	0.800
Mitchell Cr.	0.000	0.500	0.469	0.469	0.426	0.203	0.360
Noyo River Mouth	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Dark Gulch	0.000	0.000	0.000	0.000	0.000	0.000	0.000
S. Daugherty Cr.	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Mettick Cr.	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Leonaro Lake	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Martin Cr.	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Russell Brook	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Rice Cr.	0.000	0.000	0.000	0.000	0.000	0.000	0.000
James Cr.	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Chamberlain Cr.	0.000	1.470	1.337	1.337	1.045	0.453	0.615
Big River EBNF	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Big River LNF	0.000	0.190	0.175	0.175	0.174	0.089	0.142
Big River UNF	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Laguna Cr.	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Berry Gulch	0.000	1.214	1.030	1.027	0.942	0.425	0.751
Big River Mouth	0.000	0.119	0.109	0.103	0.123	0.056	0.000
Caspar Cr.	0.000	0.560	0.508	0.508	0.664	0.314	0.422
Russian Gulch	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Two Log Cr.	0.000	0.247	0.229	0.227	0.246	0.109	0.200

The values displayed in Table 6 are for year 2009, the final year modeled in the future project analysis work. The indicated increases in peak flow from projected harvesting activities both on and off of JDSF range from negligible to minor for planning watersheds with proposed JDSF harvesting. The largest increases are estimated to occur in the Two Log, Little North Fork Noyo, and Brandon Gulch planning watersheds, and are 2.8, 2.6, and 2.5%, respectively in year 2009 for the project alternative, C1 (Table 6, Figure 7). In contrast, the lowest projected increases for planning watersheds with proposed harvesting on JDSF are Mitchell Creek (0.8%) and Caspar Creek (0.6%) in 2009 for the preferred alternative (Table 6). In addition, Table 7 shows that the largest increase in peak flow over the no harvest alternative in the JDSF EIR is less than 2.3 percent for alternatives C1 and C2 in Brandon Gulch. Increases in all other planning watersheds and larger basins are much smaller.

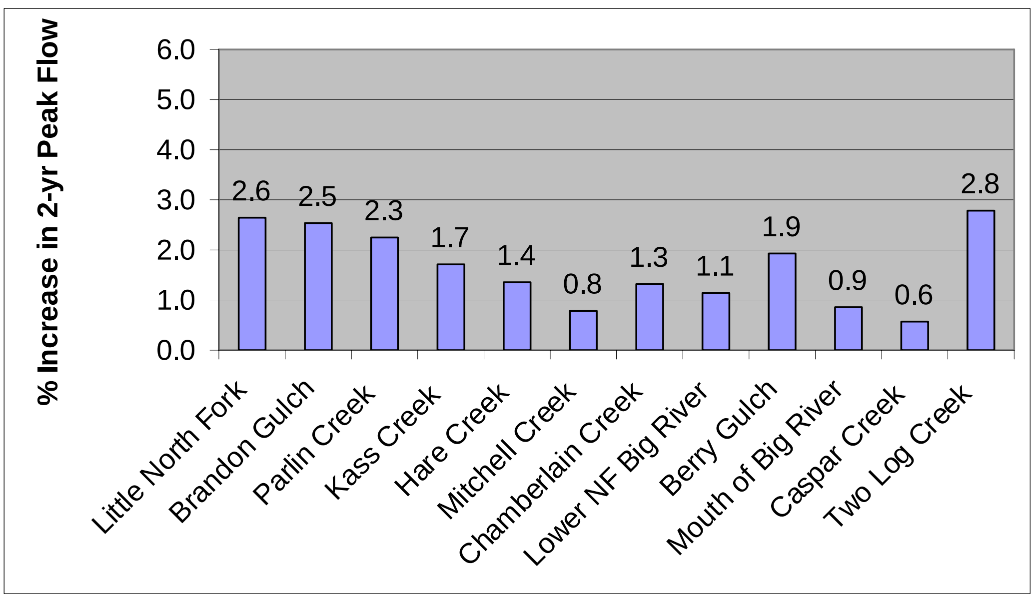

Figure 7. Modeled peak flow increases expected in year 2009 with the preferred alternative (C1) for planning watersheds where JDSF proposed management results in a change in peak flow.

As was found for the analysis of peak flows for past harvesting, projected increases in peak flows decline with increasing size of the watershed, although the reduction with watershed size is smaller. At the super planning watershed scale, the largest increase with the preferred alternative is expected to occur in the Middle Noyo River (2.6%), and the smallest calculated increase is for Upper Big River (0.6%) (Table 8 and Figure 8). At the river basin scale, the projected increase for the Noyo River and Big River watersheds are 2.1 and 1.5%, respectively, for the preferred alternative (Table 9).

Table 8. Results of the peak flow analysis with the 8 super planning watersheds [and 4 planning watersheds that flow directly to the Pacific Ocean] and the various JDSF management alternatives for the reasonably foreseeable period of 2005 to 2009. Values displayed are for year 2010, the final year modeled in the analysis.

Super Planning Watershed/Planning Watershed	Peak Flow Change (%) by Management Alternative (A-F)						
	A	B	C1	C2	D	E	F
Upper Big River	0.562	0.562	0.562	0.562	0.562	0.562	0.562
Lower Big River	1.566	1.990	1.935	1.931	1.923	1.726	1.823
North Fork Big River	0.256	0.705	0.665	0.665	0.582	0.400	0.455
South Fork Big River	2.478	2.478	2.478	2.478	2.478	2.478	2.478
Lower Noyo River	0.976	0.976	0.976	0.976	0.976	0.976	0.976
Middle Noyo River	2.644	2.647	2.647	2.647	2.650	2.647	2.644
South Fork Noyo River	0.699	2.236	2.253	2.253	2.180	1.296	1.269
Upper Noyo River	1.870	1.870	1.870	1.870	1.870	1.870	1.870
Hare Cr.	0.568	1.404	1.373	1.373	1.270	0.884	1.368
Mitchell Cr.	0.324	0.824	0.793	0.793	0.750	0.526	0.684
Caspar Cr.	0.055	0.615	0.563	0.563	0.719	0.369	0.477
Russian Gulch	0.383	0.383	0.383	0.383	0.383	0.383	0.383

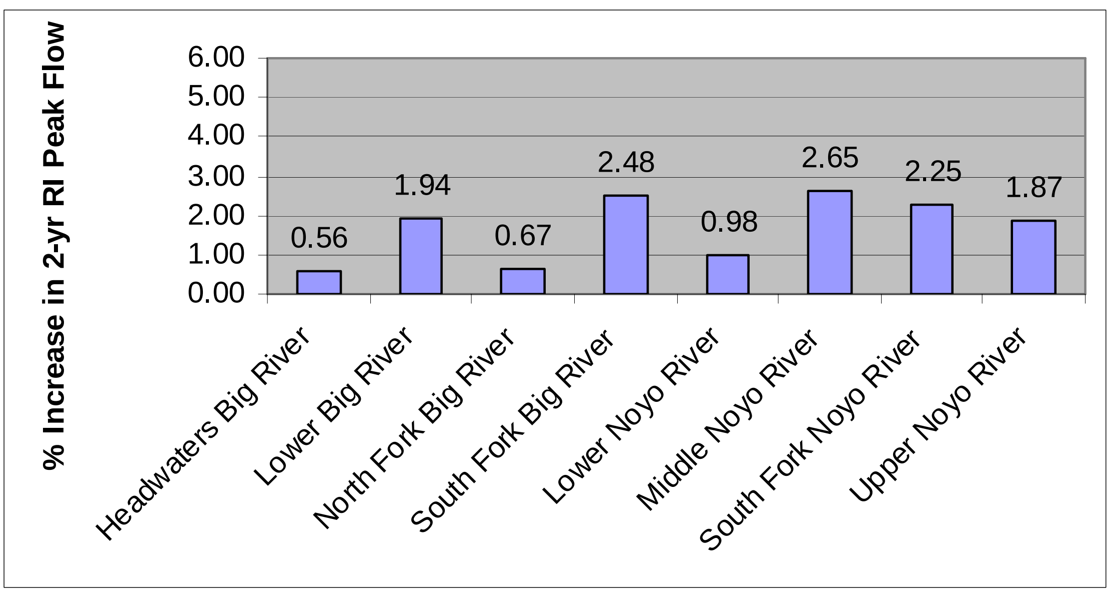

Figure 8. Modeled percent increases in 2-year recurrence interval instantaneous peak discharges under average moisture conditions for the 8 super planning watersheds (excluding the planning watersheds that drain directly into the Pacific Ocean) in the JDSF EIR assessment area with the preferred alternative, C1, in 2009.

Table 9. Results of the peak flow analysis for the river basin scale and the various JDSF management alternatives for the reasonably foreseeable period of 2005 to 2009. Values displayed are for year 2009, the final year modeled in the analysis.

River Basin	Peak Flow Change (%) by Management Alternative (A-F)						
	A	B	C1	C2	D	E	F
Noyo River	1.673	2.046	2.050	2.050	2.033	1.818	1.811
Big River	1.344	1.569	1.544	1.543	1.521	1.423	1.463

Discussion of Physical Impacts from Increased Peak Flows

Recent studies in the Caspar Creek watershed (Lewis and others 2001; Rice and others 2001) have shown that peak flow response is related to the amount of watershed disturbance, and that relative increases in storm discharge peaks and volumes decline with storm size. The mean percentage increase in peak flow averaged 35 percent in small tributary watersheds and 16 percent in partially cut larger watersheds for peaks with return periods of 0.5 years. The two-year storm had an averaged peak flow increase of 27 percent in completely clearcut watersheds, and nine percent for the approximately 50-percent-harvested North Fork of Caspar Creek (Ziemer 1998). Therefore, it can be concluded that substantial increases in 2-year recurrence interval peak flows are likely to occur in small headwater drainages that are clearcut or nearly clearcut (e.g., structure tree retention silviculture). In larger basins, such as planning watersheds, the effects on peak flows from proposed harvesting is expected to be minimal (i.e., less than 5 percent).

Grant and others (1999) summarized studies on peak flows and confirmed that peak flow increases due to harvest activities are real (statistically significant) in both small and large basins, but are more easily detected in the smaller basins. Furthermore, they state that the effect of management appears to increase peakflows of small to moderate size (up to 2-year return intervals), but these changes are within the “normal” range of streamflow variability, at least for west-side Cascade streams. However, they state that little is known about the relation between the flow regime and ecosystem response. Ziemer (1998) stated that the effect of logging on storm flow response in Caspar Creek seemed to be relatively benign, since the changes in streamflow did not appear to have substantially modified the morphology of the channel (Lisle and Napolitano 1998) or the frequency of landsliding (Cafferata and Spittler 1998). In addition, as part of the North Fork Caspar Creek study, Bottorff and Knight (1996) found little or no evidence that stream habitat was degraded or simplified by harvesting activities because forest practices minimized logging impacts.

From this analysis, and the conclusions of past studies (Lewis 2001, Grant and others 1999, Ziemer 1998), the impacts of peak flow increases that range from less than 1 to approximately 8 percent at the planning watershed scale are less than significant for both past and future projects. Under average soil wetness conditions at the start of a two-year storm event, increases of less than 1 to approximately 8 percent are less than the typical error rate for measurement of streamflow, which is commonly ± 5 to 10 percent (Gordon and others 1992). These changes are clearly within the normal range of variability of streamflows for the Coast Range, as was reported to be the case for west-side Cascade streams (Figure 9). Therefore, the predicted increase in peak flows is unlikely to be detectable in the field, and is not anticipated to adversely impact water quality. Similarly, adverse impacts to the downstream beneficial uses of water, including domestic water supply diversions and anadromous fish spawning and rearing habitats, are not anticipated from timber operations included in any of the proposed alternatives. Further details are provided in the Hydrology and Water Quality section of this document.

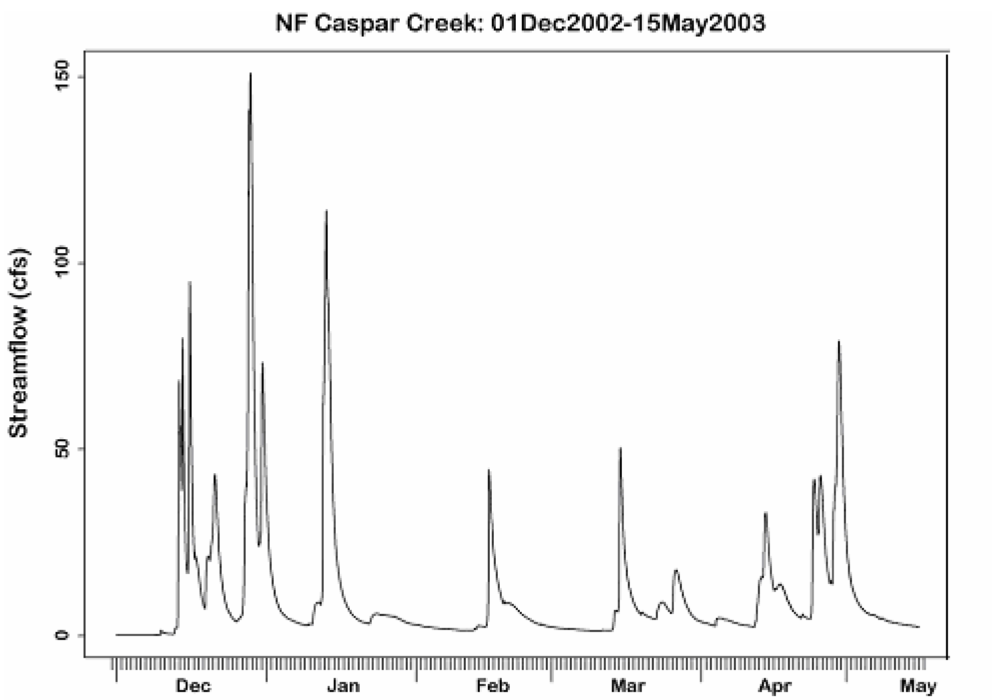

Figure 9. Plot of stream discharge for the North Fork of Caspar Creek from 01 December, 2002 through 15 May, 2003 illustrating the “flashy” nature of storm runoff hydrographs for small watersheds (plot produced by Jack Lewis, USFS-PSW, Arcata).

References

Austin, S.A. 1999. Streamflow response to forest management: a meta-analysis using published data and flow duration curves. Master of Science thesis, Colorado State University, Fort Collins. 265 p.

Cafferata, P.H. and T.E. Spittler. 1998. Logging impacts of the 1970's vs. the 1990's in the Caspar Creek watershed. In: Ziemer, R.R., technical coordinator. Proceedings from the Conference on Coastal Watersheds: the Caspar Creek Story, May 6, 1998, Ukiah, CA. General Tech. Rep. PSW GTR–168. Albany, CA: Pacific Southwest Research Station, Forest Service, U.S. Department of Agriculture. P. 103-115. http://www.rsl.psw.fs.fed.us/projects/water/caspar

Gordon, N.D., T.A. McMahon, and B.L. Finlayson. 1992. Stream hydrology: an introduction for ecologists. John Wiley and Sons, Chichester, England. P. 163.

Grant, G, W. Megahan, and R. Thomas. 1999. A re-evaluation of peak flows: do forest roads and harvesting cause floods. Proceedings of the 1999 National Council of the Paper Industry for Air and Stream Improvement (NCASI) West Coast Regional Meeting. Portland, OR. P. 5-7 – 5-9.

Lewis, J. 1998. Evaluating the impacts of logging activities on erosion and sediment transport in the Caspar Creek watersheds. *In:* Ziemer, Robert R., technical coordinator. Proceedings of the conference on coastal watersheds: the Caspar Creek story, 1998 May 6; Ukiah, CA. General Tech. Rep. PSW GTR-168. Albany, CA: Pacific Southwest Research Station, Forest Service, U.S. Department of Agriculture; 55-69.

Lewis, J., S.R. Mori, E.T. Keppeler, and R.R. Ziemer. 2001. Impacts of logging on storm peak flows, flow volumes and suspended sediment loads in Caspar Creek, California. *In:* Mark S. Wigmosta and Steven J. Burges (eds.) Land Use and Watersheds: Human Influence on Hydrology and Geomorphology in Urban and Forest Areas. Water Science and Application Volume 2, American Geophysical Union, Washington, D.C.; 85-125.

Lisle, T.E. and M. Napolitano. 1998. Effects of recent logging on the main channel of North Fork Caspar Creek. *In:* Ziemer, Robert R., technical coordinator. Proceedings of the conference on coastal watersheds: the Caspar Creek story, 1998 May 6; Ukiah, CA. General Tech. Rep. PSW GTR-168. Albany, CA: Pacific Southwest Research Station, Forest Service, U.S. Department of Agriculture; 81-85.

Lisle, T.E., L.M. Reid, and R.R. Ziemer. 2000. Review of: Freshwater flooding analysis summary. Unpubl. report prepared by the USDA Forest Service Pacific Southwest Research Station, Redwood Sciences Laboratory, Arcata, CA. 31 p.

MacDonald, L.H., 2000. Predicting and managing cumulative watershed effects. Proceedings, Watershed Management 2000, American Society of Civil Engineers, 10 pp.

MacDonald, L.H. and S. Litschert. 2003. Documentation for DELTA-Q Program. Unpublished Report. Colorado State University, Fort Collins, CO. 10 p. http://www.cnr.colostate.edu/frws/people/faculty/macdonald/cwemodel/DeltaQ_docs.PDF

MacDonald, L.H., Smart, A.W., and Wissmar, R.C.: 1991, Monitoring guidelines to evaluate
effects of forestry activities on streams in the Pacific Northwest and Alaska, Seattle, Washington, U.S. Environmental Protection Agency Region 10, Water Division, EPA/910/9-91-
001, 166 p.

Mount, J.F. 1995. California rivers and streams. University of California Press, Berkeley, CA.

Rice, R.M., R.R. Ziemer, and J. Lewis. 2001. Forest management effects on erosion, sediment, and runoff: Lessons from Caspar Creek and northwestern California. Pages 69-75 in: Proceedings, Society of American Foresters 2000 National Convention, November 16-20, 2000. Washington, DC: Society of American Foresters.

Toman, E.M. 2004. Forest road hydrology: the influence of forest roads on stream flow at stream crossings. Master of Science Thesis, Oregon State University, Corvallis, OR. 78 p.

U.S. Fish and Wildlife Service and California Department of Forestry and Fire Protection (USFWS and CDF). 1999. Final Environmental Impact Statement/Environmental Impact Report for the HCP/SYP, Headwaters Forest Project. January 1999. p. 3.4-21.

Ziemer, R.R. 1992. Effect of logging on subsurface pipeflow and erosion: coastal northern California, USA. *In:* Walling, D.E.; Davies, T.R.; Hasholt, B., eds. Erosion, debris flows and environment in mountain regions, Proceedings of the Chendu symposium; 1992 July 5-9; Chendu, China. International Association of Hydrological Sciences Publication No. 209. Wallingford, UK: IAHS; 187-197.

Ziemer, R.R. 1998. Flooding and stormflows. *In:* Ziemer, Robert R., technical coordinator. Proceedings of the conference on coastal watersheds: the Caspar Creek story, 1998 May 6; Ukiah, CA. General Tech. Rep. PSW GTR-168. Albany, CA: Pacific Southwest Research Station, Forest Service, U.S. Department of Agriculture; 15-24.

Ziemer, R.R. and T.E. Lisle. 1998. Chapter 3. Hydrology. Pages 43-68, *in:* Naiman, Robert J., and Robert E. Bilby, eds. River Ecology and Management: Lessons from the Pacific Coastal Ecoregion. Springer-Verlag, N.Y. http://www.humboldt.edu/~rrz7001/pubs/Ziemer98a.PDF

Ziemer, R.R., and R.M. Rice. 1990. Tracking rainfall impulses through progressively larger drainage basins in steep forested terrain. *In:* Lang, H.; Musy, A., eds. Hydrology in mountainous regions. I - Hydrological measurements; the water cycle, proceedings of two Lausanne symposia, 1990 August. International Association of Hydrological Sciences Publication No. 193. Wallingford, UK: IAHS; 413-420.